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ABSTRACT

This paper is a preliminary inquiry by a non-mathematician into graphic methods of sequential planning and ways in which hierarchical analysis and tree structures can be helpful in developing interest in the use of mathematical modeling in the search for creative solutions to real-life problems. Highlights include a discussion of hierarchical concepts, probability, and several types of tree structures; a description of the tree methodology used for an introductory course in ethics; a brief history of spatial and abstract hierarchies, the human hierarchy, and a hierarchy of personal achievement; an explanation of Saaty's four-level Analytic Hierarchy Process; a description of a method for quantifying relative values using the Pairwise Comparison Scale; and a discussion of tree structure use of specifying and evaluating goals as graphic aids to decision making. Detailed descriptions and diagrams are given of the use of the decision tree methodology in the ethics course, which includes several sessions on values; a module on decision analysis in ethics; a presentation of the concepts of probability, expected value, and quantitative methods of obtaining optimal value judgments in a biomedical situation; study materials; decision-making exercises to be completed by drawing trees; and assignments. Procedures for analyzing the trees are also provided. Several tables, diagrams, and a variety of examples of tree structures that have been used to facilitate research in several disciplines are included. (DJR)

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"FROM FAMILY TREES TO DECISION TREES"

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Presented at the Fifteenth Annual Conference of the
International Society for Individualized Instruction

A Society for Exploring Teaching Alternatives

October 9-11, 1986
Ramada Renaissance Hotel
Atlanta, Georgia

Acknowledgments

1 - Figures from Moshe F. Rubinstein, TOOLS FOR THINKING AND PROBLEM SOLVING, 1986. pp, 180-181, 285. Reprinted by permission of Prentice-Hall, Inc., Englewood Cliffs, New Jersey. (Letter August 5, 1986).

2 - Figures from Thomas L. Saaty, DECISION MAKING FOR LEADERS, 1982. Wadsworth, Belmont, California. Permission granted by Van Nostrand Reinhold Company, Inc., 115 Fifth Avenue, New York, New York. (Letter August 19, 1986).

3 - Figures from Robert T. Francoeur, BIOMEDICAL ETHICS: A GUIDE TO DECISION MAKING, 1983, John Wiley and Sons, Inc., Reprinted by permission of John Wiley & Sons, Inc. (Letter Dec. 16, 1985).

4 - Appreciation is extended to Dr. Samuel Goldberg, Sloan Foundation, for introducing me to Thomas L. Saaty's books.

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  Cartoon - soup tasting decision

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- SAATY'S ANALYTICAL HIERARCHY PROCESS
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  - Political Tree - Voting Behavior
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  - Classification Binary Tree - Biology Field Work
  - Manuscript Linkage Problem
  - Braverman's Timed multi-stage Decision Tree
  - Mountain Pass Transportation Decision Tree

  Cartoon - statistical beast

ISII Conference
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INTRODUCTION

Since the theme of this conference is "Thinking Across the Disciplines," and the ISII is "A Society for Exploring Teaching Alternatives," I reflected on certain concepts and techniques that appear relevant to several disciplines. In addition, because Bennett College is a women's college, we have become increasingly concerned with encouraging interest in quantitative reasoning, and we are successfully alleviating the old stereotype that women "can't do math, think logically, or make decisions by themselves."

This paper is a preliminary inquiry by a non-mathematician into graphic methods of sequential planning and ways that hierarchical analyses and tree structures can be helpful in developing interest in the use of mathematical modeling in the search for creative solutions to real-life problems.

There are decision problems (especially in humanities and social sciences) in which both qualitative and quantitative aspects are combined as judgment and prior experience lead to examination of alternative consequences of the action to be taken. Also, the increased use of personal computers in colleges and the need for computer literacy reflects that "tree methodology is a child of the computer age" (Brieman, et al, viii).

I will look briefly at hierarchical concepts, probability, and several types of tree structures prior to describing decision tree methodology that was used in a class last semester. As an appendix, a variety of examples of tree structures that have been used to facilitate research in several disciplines can be shown. It is hoped that this effort will stimulate thought about ways to encourage "quantitative literacy."

"Mmm. The soup du jour is not cream of mushroom. It is not tomato or celery. It is not chicken, nor is it Scotch broth. It is most definitely not won ton..."

Drawing by Ziegler; © 1980 The New Yorker Magazine, Inc.

HIERARCHICAL CONCEPTS

It is generally agreed that hierarchical ordering is basic to human thought. Think of the hierarchical classification of:

- numbers, scales, times, positions, crystal forms, symmetry elements, and groups;
- symbolisms, sentences, and languages of all kinds;
- logical types, concepts, principles, information, quantities, and abstractions of many other sorts. (White 9)

The idea of hierarchy includes various controversies. The word is derived from the Greek hieros (sacred) and archos (ruler). Most references attribute the word to Dionysius the Areopagite, a fourth century disciple of St. Paul who is said to have written a book entitled De Coelesti Hierarchia. (For biblical reference see the book of "Acts" in the New Testament, Chapter 17, verses 32-34). He is referred to by Dante in Canto X and Canto XXVIII of The Divine Comedy as having seen several heavenly orders of angelic and priestly choirs (Bk. 20, p. 406 and notes 3 and 5 in Harvard Classics edition). Plato treats hierarchical concepts in his Dialogues and Aristotle was concerned with hierarchical structures in nature. Conjectures about spatial and abstract hierarchies continue throughout the history of ideas, and appear today in histories of General Systems Theory and in the literature of all disciplines studying complex situations. (See Klir, 21-24) The history of this idea links science and religion, literature and philosophy, mathematics and other disciplines.

The human hierarchy, as described by various persons, moves from the physiological, through the psychological to the sociological, (Milsum 154),

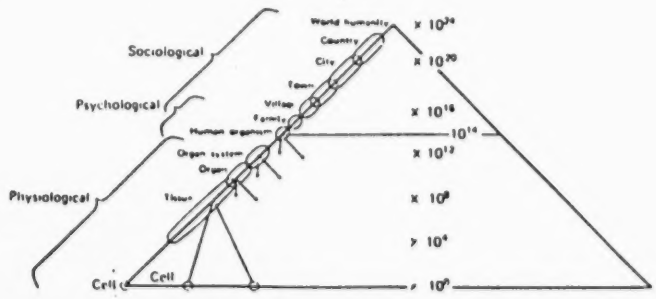

Figure 5.1. The human hierarchy. The multiple subsystems at any level are suggested by the several radiating lines. The variation in size at any level is suggested by the length of the link.

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The human development stages of Erickson, Graves and Maslow have been combined in a "hierarchy of personal achievement" (Milsum 153).

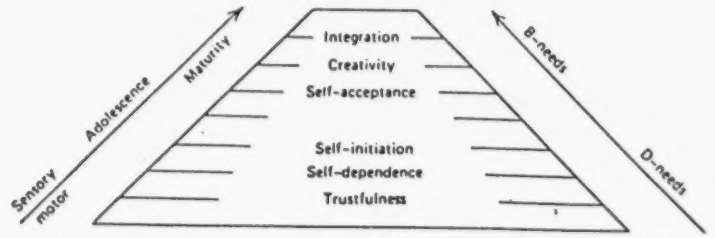


Figure 5.4. Stages of psychophysiological development in man—inferred from Erikson [14], Graves [13], and Maslow [12].

Thomas L. Saaty describes applications of the Analytic Hierarchy Process ranging from personal decisions to high level corporate and governmental conflict resolutions. He feels that this method combines the deductive approach to problem solving with the systems approach, establishes priorities and puts into an "integrated, logical framework" a focus on the parts along with the workings of the whole (2). A series of hierarchies given by Saaty in Decisions for Leaders illustrate ways to break down problems or objectives into separate elements or levels, how to rank the elements by relative importance, and how to ensure some degree of logical consistency. In this hierarchy for choosing a school thesix criteria: educational, vocational, sports, cultural, social and spiritual are given a series of subcriteria and each school is then prioritized with respect to those subcriteria (34).

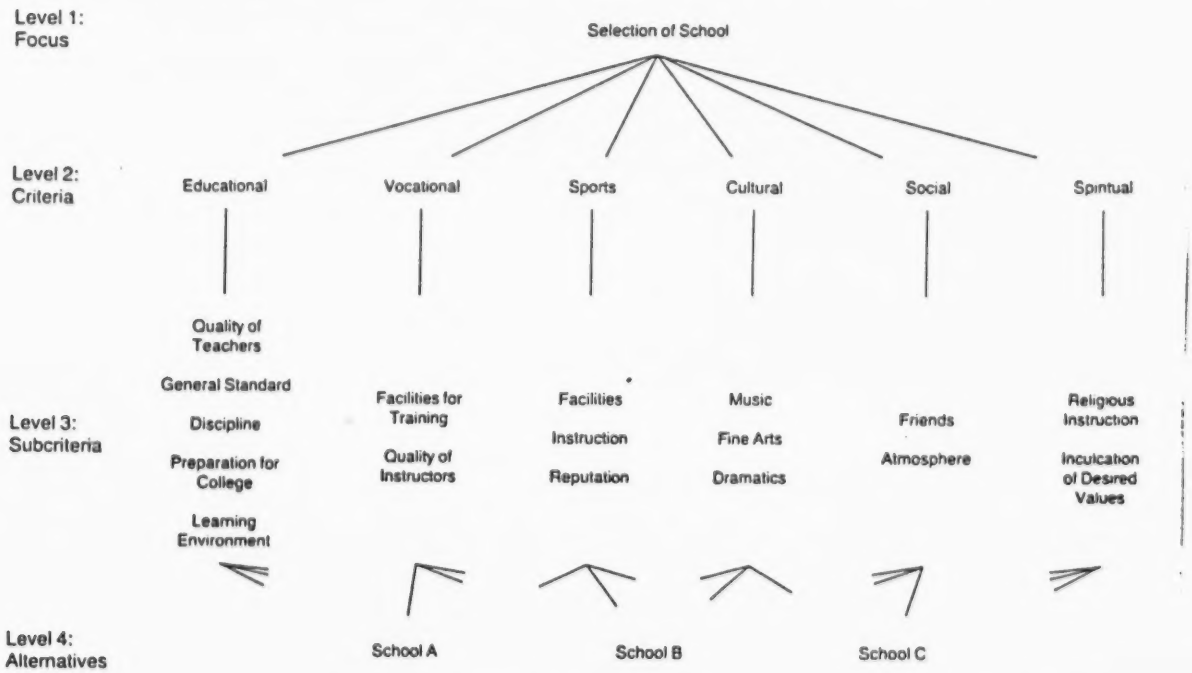


Figure 4-16 Hierarchy for Choosing a School

A method for quantifying relative values by creating a matrix of relative weights is described by Saaty. A pairwise comparison scale provides a matrix for calculation (Saaty and Alexander 148).

Table 5-1 The Pairwise Comparison Scale

Intensity of Importance	*Definition*	*Explanation*
1	Equal importance of both elements	Two elements contribute equally to the property
3	Weak importance of one element over another	Experience and judgment slightly favor one element over another
5	Essential or strong importance of one element over another	Experience and judgment strongly favor one element over another
7	Demonstrated importance of one element over another	An element is strongly favored and its dominance is demonstrated in practice
9	Absolute importance of one element over another	The evidence favoring one element over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between two adjacent judgments	Compromise is needed between two judgments
Reciprocals	If activity *i* has one of the preceding numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	

As an example of a personal decision Saaty demonstrates an entire hierarchy structured by "a woman who has recently earned her Ph. D. and is being interviewed for three jobs. Which one should she choose?" ... "each element in a level is evaluated in terms of all the elements in the next higher level." Level 1, the focus or goal, is called "Overall Job Satisfaction"; the Level 2 criteria: Research, Growth, Benefit, Colleagues, Location, Reputation are the criteria that she feels will make contributions to her job satisfaction; and Level 3 represents the three different opportunities. By using the Pairwise Comparison Scale a matrix of the criteria with respect to the focus was prepared, then six matrices for comparing the three jobs with respect to each criterion. Reputation turned out the most important for her, followed by growth and benefits. "All three entries in the vector of priorities obtained in each of the six matrices and listed in the last column of each are multiplied (weighted) by the priority of the corresponding criterion. The results of this operation are then added to yield the overall priorities for the jobs. (A=.40, B=.34, C=.26)." (Saaty 85-86) The slide shows pairwise comparisons for the six criteria and the figures that prioritized the jobs sufficiently to influence the candidate toward Job A.

TABLE 8.4

Overall satisfaction with job	Research	Growth	Benefits	Colleagues	Location	Reputation	Eigenvector
Research	1	1	1	4	1	1.2	0.18
Growth	1	1	2	4	1	1.2	0.19
Benefits	1	1/2	1	5	3	1.2	0.19
Colleagues	1/4	1/4	1/5	1	1/3	1/3	0.05
Location	1	1	1/3	3	1	1	0.12
Reputation	2	2	2	3	1	1	0.30

Now each job is compared with each of the other jobs with respect to how they bear upon each of the six criteria (Table 8.5).

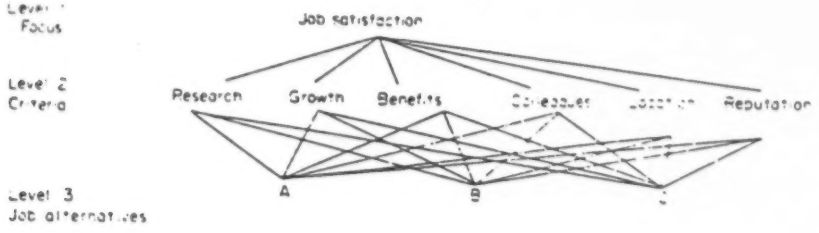


FIG. 8.2

TABLE 8.5

Research	A	B	C
A	1	1/4	1/2
B	4	1	3
C	2	1/3	1

Growth	A	B	C
A	1	1/4	1/5
B	4	1	1/2
C	5	2	1

Benefits	A	B	C
A	1	3	1/3
B	1/3	1	1
C	3	1	1

Colleagues	A	B	C
A	1	1/3	5
B	3	1	7
C	1/5	1/7	1

Location	A	B	C
A	1	1	7
B	1	1	7
C	1/7	1/7	1

Reputation	A	B	C
A	1	7	9
B	1/7	1	5
C	1/9	1/5	1

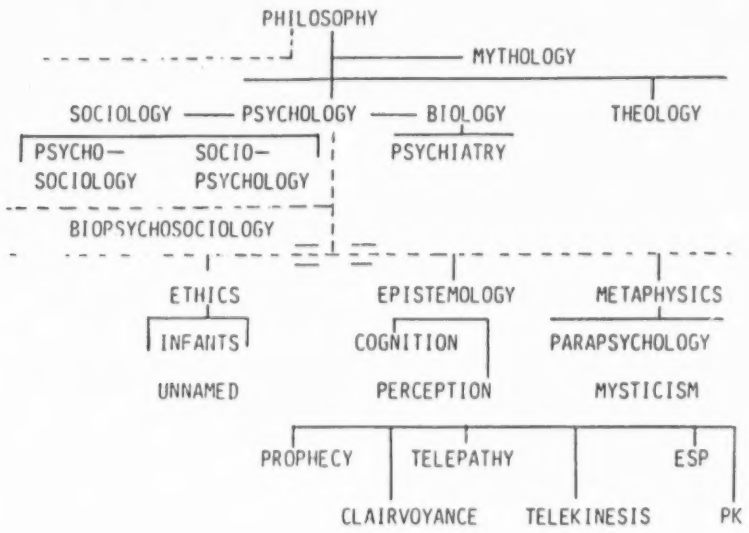
The eigenvectors (one for each criterion) just obtained are each weighted by the eigenvector component of the associated criterion and the results summed and normalized. We obtain:

$$0.16\begin{bmatrix}0.14\\0.63\\0.24\end{bmatrix} + 0.19\begin{bmatrix}0.10\\0.33\\0.57\end{bmatrix} + \cdots + 0.30\begin{bmatrix}0.77\\0.17\\0.05\end{bmatrix} \longrightarrow \begin{bmatrix}0.40\\0.34\\0.26\end{bmatrix}\begin{matrix}A\\B\\C\end{matrix}$$

We have prioritized the jobs. The differences were sufficiently large for the candidate to accept the offer to job *A*.

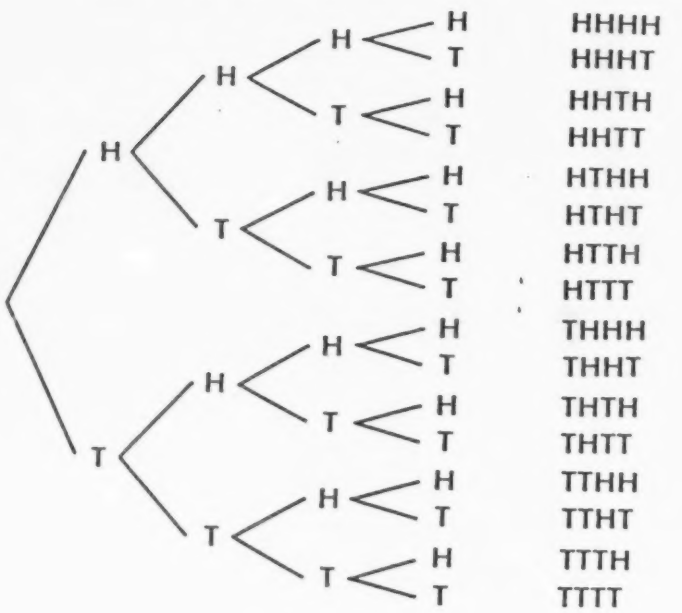
TREE STRUCTURES

Hierarchical methods are a reminder that there are also tree structure techniques for specifying and evaluating goals as well as classifying, analyzing choices, and quantifying expected outcomes. Trees are a time-honored graphic method. Map makers draw rivers and their tributaries. At an advanced age my father made detailed family trees proving that three hereditary Mennonite lines (Swiss, German and Irish) met early in the 1800s in his family. Here is a family tree for the discipline of psychology.



THE GENEALOGY OF PSYCHOLOGY

Mathematicians construct probability trees in order to express the measurement of chances or the terms of odds. One way of showing expected outcomes is with tree diagrams such as can be made for a simple coin tossing experiment (Jacobs 344).


First coin
Second coin
Third coin
Fourth coin
Outcome
H
T
HHHH
HHHT
HHTH
HHTT
HTHH
HTHT
HTTH
HTTT
THHH
THHT
THTH
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TTHH
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TTTH
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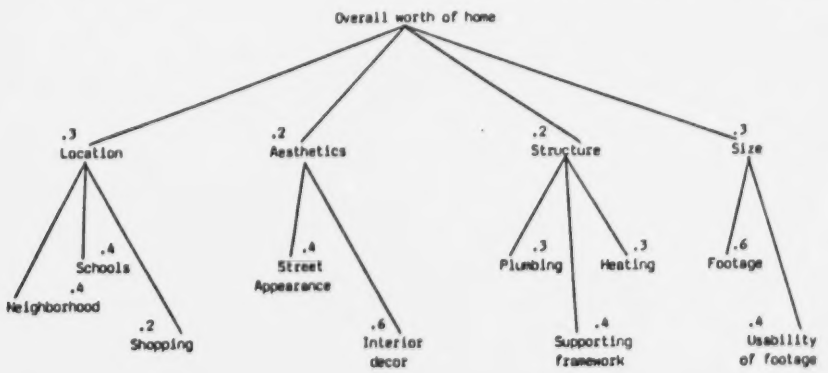
Two types of trees, useful as graphic aids to decision making are worth trees and relevance trees. Assuming an adequate source of information, a tree can serve as a preliminary model for the allocation of resources based on value judgments. Consider a worth tree for the purchase of a home. Here is a tree chart from Austin and Burns's Management Science (481-482). Imagine that you want to purchase a home and are now at the stage of deciding which one of three homes will be worth the most to you. The tree is constructed by choosing four main aspects representing overall worth of the home; location, aesthetics, structure, and size. These may be called the "higher level attributes." For each of these attributes the significant factors associated are then subsumed as "lower level attributes." A value of zero to one is assigned each attribute representing an estimate of satisfaction with the particular item being evaluated. A relative "benefit coefficient" associated with each value will also add to no more than one. This will be an intuitive estimate of the particular benefit of the item. Note that on this tree the essential factors to be considered concerning the LOCATION are the neighbord, schools, and shopping facilities. Other branches could be added. The values of all branches would add to 1, and so on for each of the attributes. Assuming that you have intuitively forecasted benefit coefficients for each of your lower level attributes (of each of the three prospective homes) you can now compute the worth value of a home.



This table shows the calculations. A worth/cost ratio is obtained by dividing the overall worth by the cost. The authors of Management Science comment that "the home purchase problem is indicative of the way in which multi-attribute utility theory is applied to multi-faceted subjects to assess their overall worth" (482).

TABLE - THREE HOMES CONSIDERED FOR PURCHASE

Attribute	Home 1	Home 2	Home 3
Neighborhood	.7	.8	.9
Schools	.6	.7	.7
Shopping	.8	.9	.3
Street appearance	.9	.6	.8
Interior decor	.5	.7	.9
Plumbing	.8	.8	.4
Supporting framework	.8	.8	.4
Heating	.7	.7	.3
Footage	.8	.9	.7
Usability of footage	.8	.9	.7
Overall calculated worth	.742	.778	.666
Asking price	$98,000	$105,000	$69,000
Overall worth/cost	.00000757	.00000741	.00000965

Using the table given here the worth value of home 1 is obtained by multiplying the worth of the lower level attributes of each branch by their respective benefit coefficients. These products are then added. Thus for home 1 we have

Location worth = .4(.7) + .4(.6) +.2(.8) = .68
Aesthetics = .4(.9) + .6(.5) = .66
Structure = .3(.8) + .4(.8) + .3(.7)= .77
Size = .6(.8) + .4(.9) = .84

Each of these calculated worths for the location, aesthetics, structure, and size are now multiplied by the comparative value assigned these factors. Overall worth of home 1 = .3(.68)+.2(.66) + .2(.77) + .3(.84) = .742.

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Compare the worth tree with Saaty's hierarchy for purchasing a house.

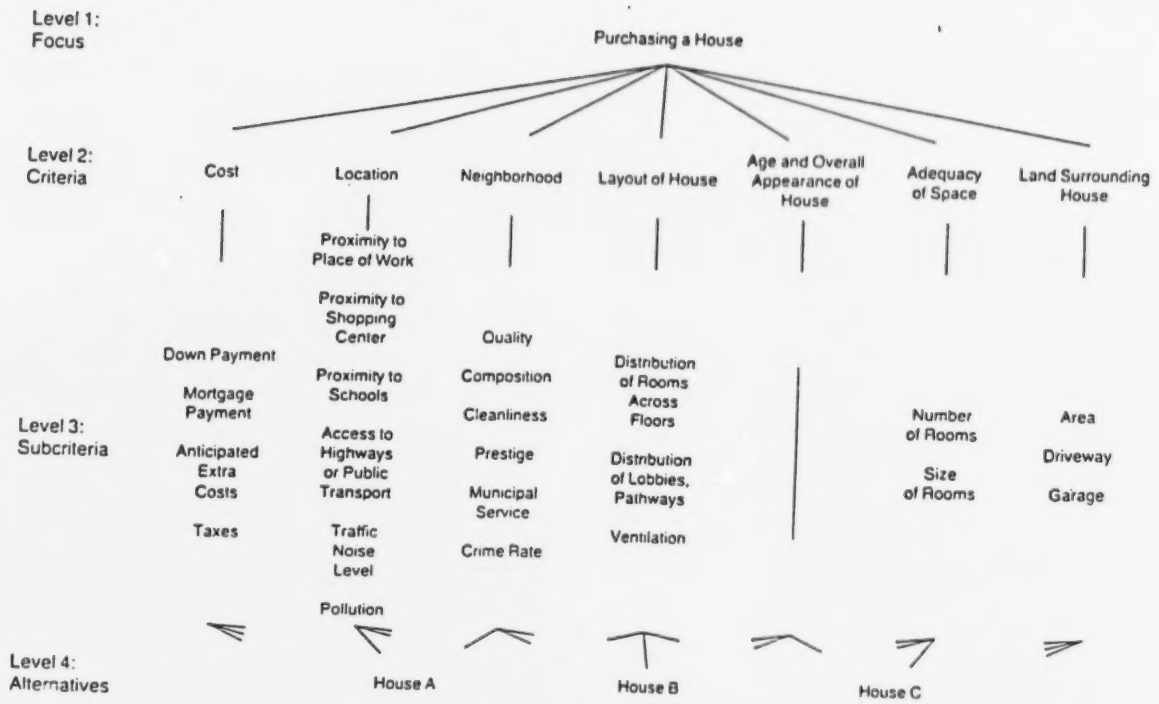


Figure 4-17 Hierarchy for Purchasing a House

Relevance trees are comparable to worth trees. Waddington describes relevance trees as "hierarchically ordered networks of objectives. . . A vertical relevance tree relates a long-term objective to the alternative actions that should be taken in order to achieve that objective" (216).

Rubinstein's discussion of relevance trees gives a precise sequence of steps by which to reflect the most accurate value judgment. Using the same basic idea seen earlier as a hierarchy for job selection note this "Best Job" tree and its calculations. Using an abbreviated version of Rubinstein's nine steps I constructed a "Best Auto" tree. Recently I bought a new car and all my figures would now be very different! Here are the nine steps (288-289).

NINE STEPS TO CONSTRUCT RELEVANCE TREES

1) Establish broad categories relevant to the problem.

2) Assign a weight to each broad category.

3) Subdivide the broad categories into more refined components.

4) Continue step 3 to a satisfactory level of refinement.

5) Calculate the ratings of importance r_j for the attributes.

6) Assign values to the contributions c_{ij} that each alternative a_i makes to attribute $j = 1, 2, \ldots, m$.

7) Establish reasonable upper and lower limits for each attribute.

8) Calculate the value $v(a_i) = \sum_{j=1}^{m} c_{ij} r_j$

9) Study the results of step 8 and modify your model where necessary.

(Rubinstein, 288-289)

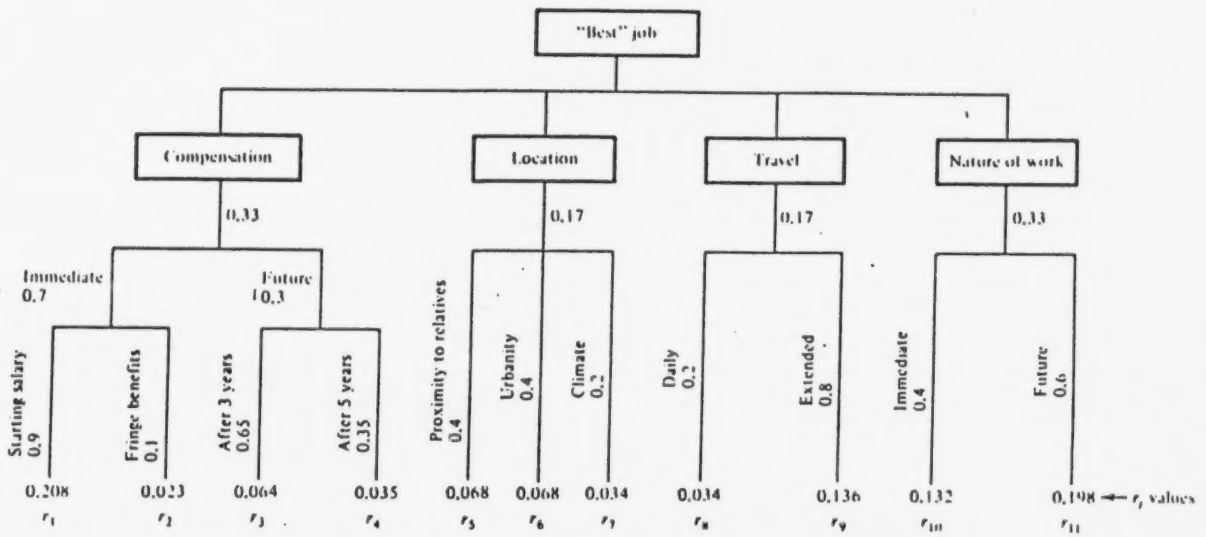
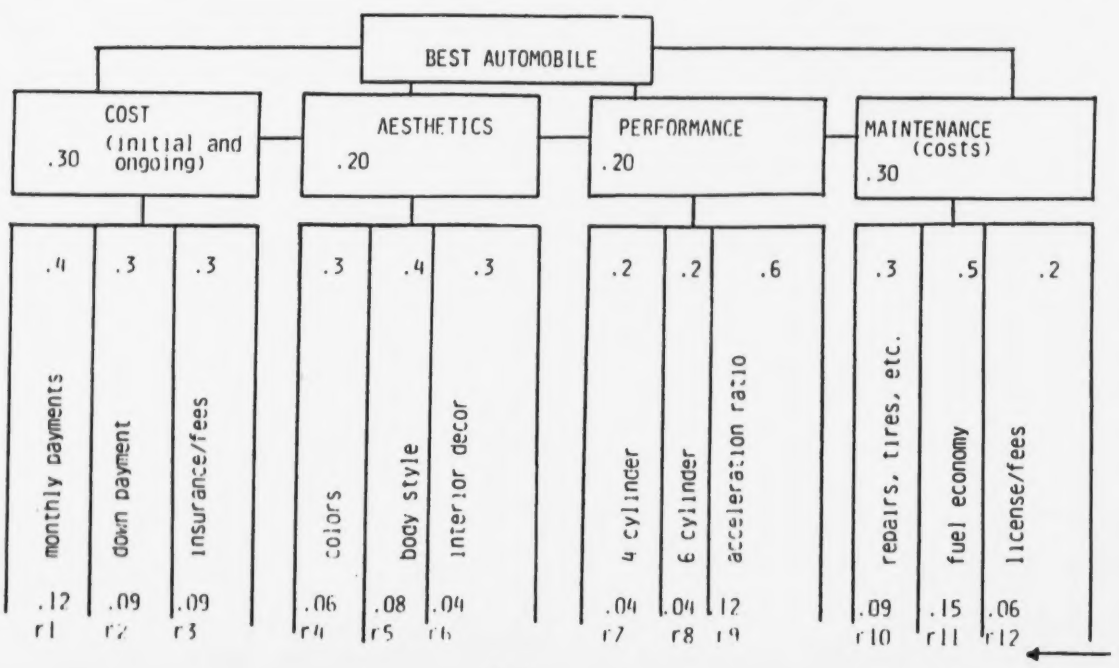


Figure 8.18 Relevance tree for job selection. For best job a_B^*, $c_{Bj} = 1$ for all j, $V(a_B^*) = \Sigma c_{Bj} r_j = 1$. For worst (barely acceptable) a_W^0, $c_{Wj} = 0$ for all j, $V(a_W^0) = \Sigma c_{Wj} r_j = 0$.



Now for an account of the use of decision tree methodology in an Introduction to Ethics course. Following several sessions on values (including skits or simulations on abortion issues, stage theories, and ethical theories) a module on decision analysis in ethics was team taught. Dr. Ray Treadway, Professor of Mathematics, presented students with concepts of probability, expected value, and quantitative means of obtaining optimal value judgments in a biomedical situation. Students were given purchased copies of Chapter Ten "Decision Tree Technique" from Francoeur's BIOMEDICAL ETHICS: A GUIDE TO DECISION MAKING. While this was being studied Dr. Treadway assigned simple probability exercises and elementary exercises to be completed by drawing trees. (e.g., umbrella problem, a business decision, a swine-flu dilemma for decision concerning immunization).

The students were now ready for Francoeur's tree concerning an 87 year old invalid widow with a 50/50 chance of surviving an inoperable dormant tumor. "The decision is whether or not to prescribe medication to prevent a reactivation of the suspected malignant growth. The medication being considered is effective but has some side effects, which may be minor or serious" (120).

Here is the first tree. It starts with an initial decision and branches to the right. In a decision tree the choices are represented by lines on branches that emanate from a node, usually a square box. States of nature or chances are represented by circles. Together these elements describe the situation. A table is given of "Chance Events and Their Probabilities." An assumption was made that adequate medical statistics had already been done. Now these probabilities have been entered in parentheses and values of each potential outcome are shown on the far right side of the tree. The circled figures from 0 to -5 represent the extent to which serious complications may be expected.

TABLE 10.1 Chance Events and Their Probabilities

Event	Probability (%)	Event	Probability (%)
Tumor is present	50	Tumor is absent	50
Tumor reactivates	35	Tumor remains dormant	65
Medication causes side effects	90	Medication causes no side effects	10
Side effects are major	20	Side effects are minor	80

This step completes construction of our decision tree. Learning to use this diagram is our next task.

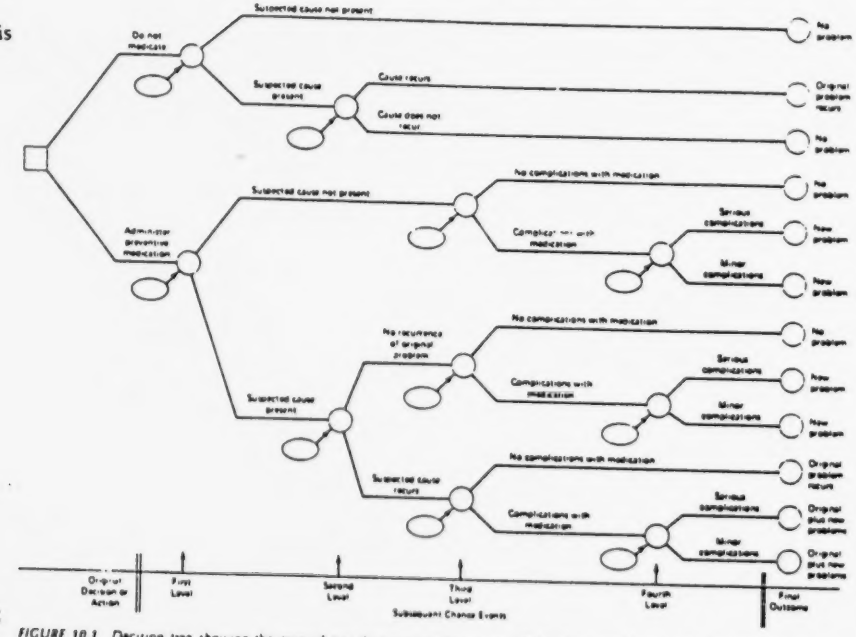


FIGURE 10.1 Decision tree showing the original two decisions or actions considered, their possible or likely consequences (chance events), and final outcomes.

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The next procedure for analyzing decision trees is called "rolling back and averaging out." One must multiply the assigned value at the end of a branch by its associated probability figure and repeat to obtain other subtotals and then add subtotals together to obtain the calculated value. On this tree these figures have been entered in an ellipse with an arrow pointing to the appropriate node. Start at the far right bottom multiplying each branch in the fourth level: -4 x .8 = 3.2. Next line up: -5 x .2 = -1. "Add these two subtotals and you have the calculated value for the node leading to these two outcomes: -3.2 + -1.0 = -4.2. For the third level the process is repeated and for the final node on the first level the figures are -1.61 and -.53. So the optimal decision is the action "with the lowest first level calculated value, in this case of -.53. . . The decision is not to give the preventive medicine" (123).

Following this tree Dr. Treadway devised two assignments. The first stated conditions, the second asked students to revise the conditions. Trees were drawn, values listed, calculations made, and final results were accomplished by computer software called DECIDE.

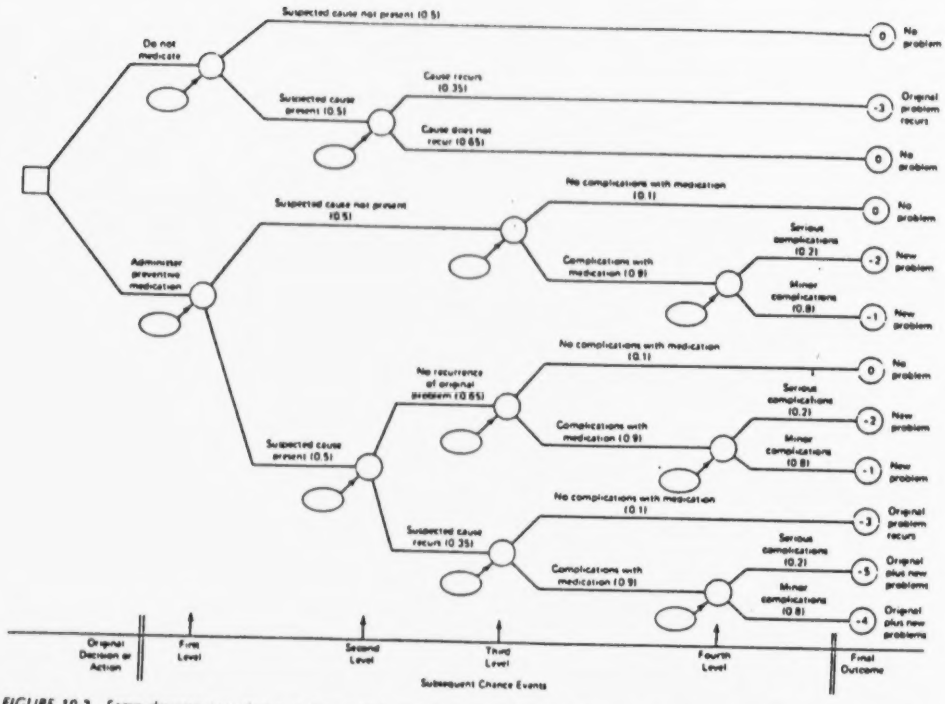

FIGURE 10.2 Same decision tree shown in Figure 10.1, with assigned values listed for each final outcome on the far right and with probability estimates given in parentheses for each chance event.

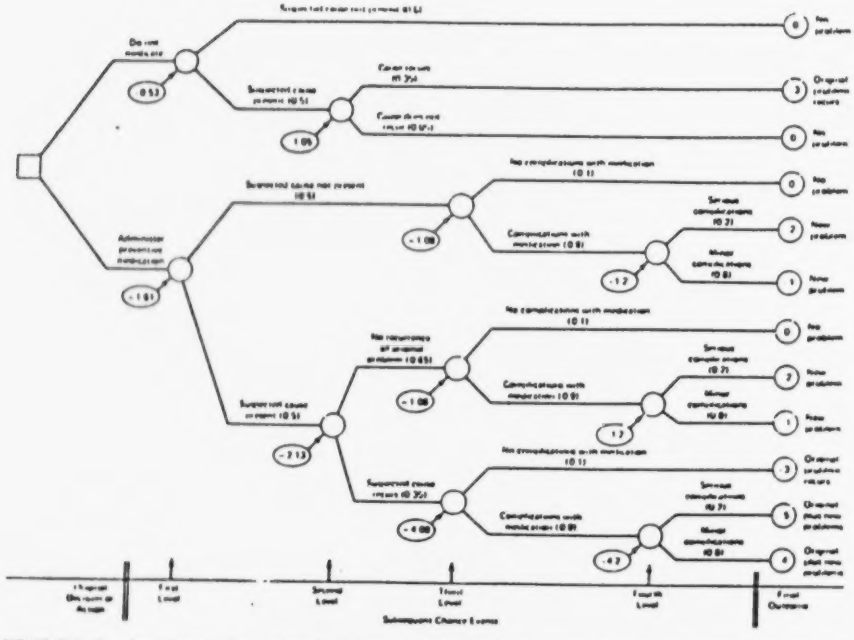

FIGURE 10.3 Completed version of Figure 10.1 decision tree. Calculated values have been worked out for each event node and entered on the sliding lines with arrow pointing to the event node.

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To illustrate the use of trees in various disciplines I have selected several examples. In religious studies when the word "tree" is mentioned we tend to think of the "Tree of Knowledge," "Tree of good and evil," or the medievalists "Tree of vices." In mathematics a tree "network is one that does not have any loops" (Jacobs 470). There is even a straight line, that with a few points demarked is termed a "linear tree." Under the terminology of "additive" trees there are also ultrametric and singular and combinations. (Sattath and Tversky 340).

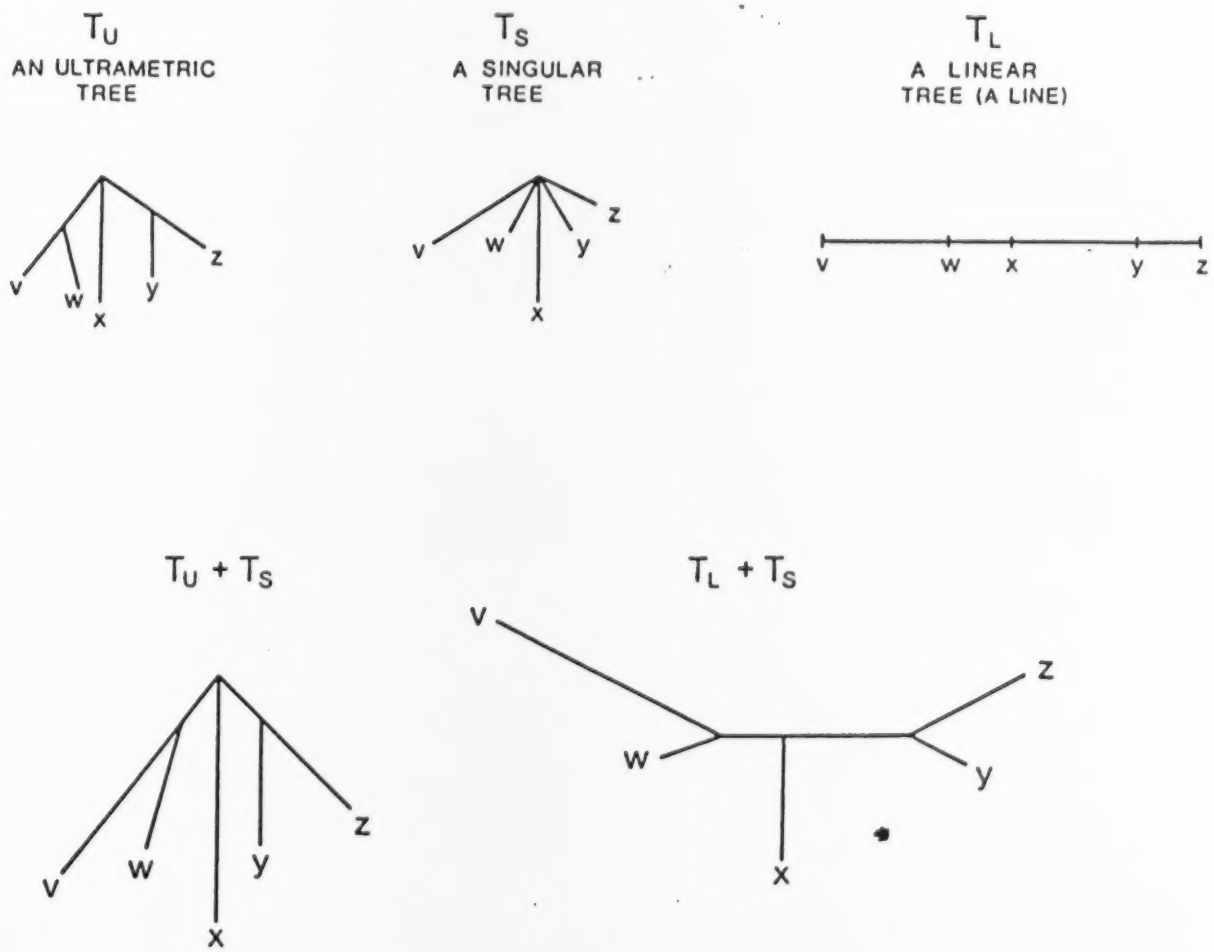

FIGURE 13
An illustration of different types of additive trees.

Rubinstein, in Tools for Thinking and Problem Solving, under the heading of "Concepts from Information Theory" explains the "Huffman Tree Construction Algorithm." This can be used "in optimal merging of lists, construction of search trees, generating of high-quality computer codes. . . compressing of data, and even checking for leaks in a pipeline" (183).

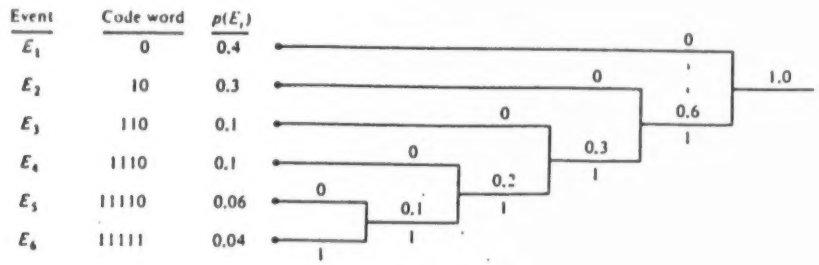

Figure 5.23 Huffman tree structure for code of six events.

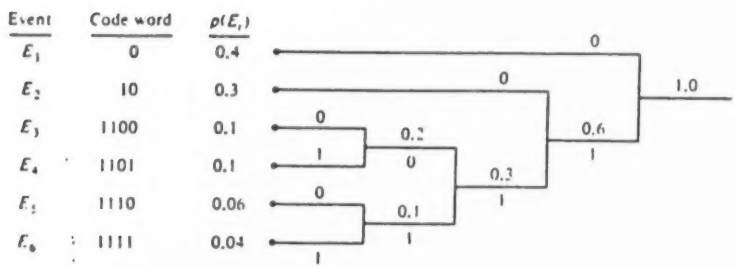

Figure 5.24 Alternative code for the events of Figure 5.23.

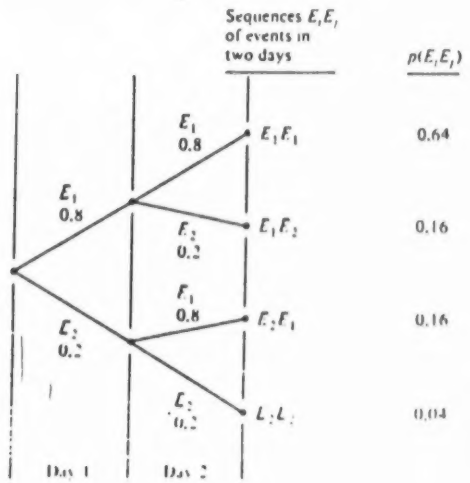

Figure 5.25

An example of a "partial value assessment" structure for a social work agency, shows how each goal can be given numerical value, "and the objectives that are derived from those goals can be given weights reflecting their contribution to the higher-level objectives." Drezner suggests this method as a means of "meaningful dialogue." Even with "value-laden" disagreements the program-planning process of stating goals, objectives, and priorities is improved because both communication and participation encourage "insight into the behavior of the organization" and therefore "more relevant decisions" (11).

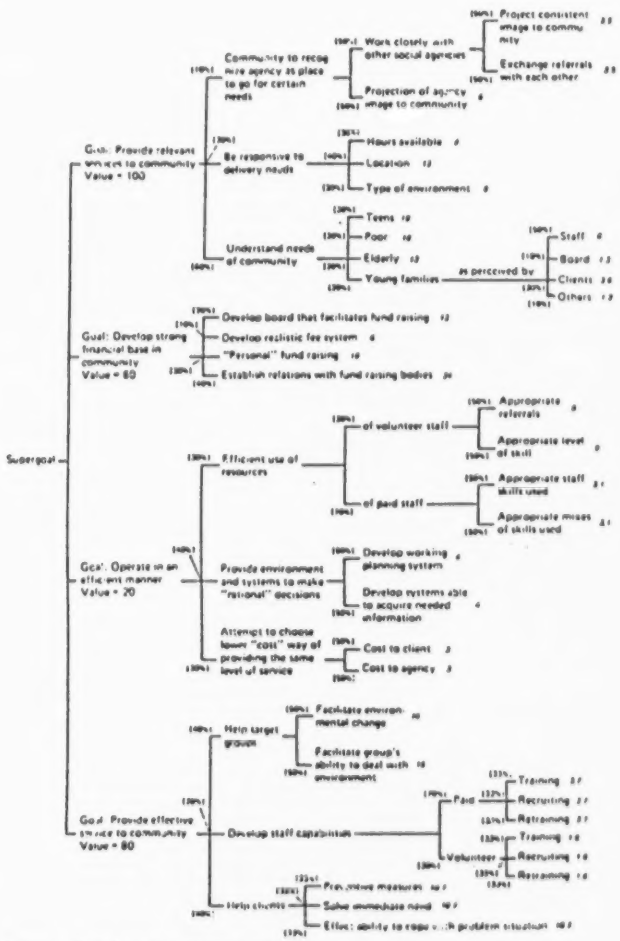

Figure 2. Partial value assessment structure

Goals rated on a scale of 0–100.
Percentage considerations shown in brackets.
Calculated value of lowest level objective shown in italics.

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Some other examples of trees as research aids have been developed by Amos Tversky and Shmuel Sattath.

> A probabilistic choice model called preference tree or pretree describes choice as a covert hierarchical elimination process. Each alternative is represented as a measurable collection of aspects, and the entire ensemble of aspects is assumed to have a tree structure. At each stage one selects an aspect (i.e., a branch of a tree) with probability that is proportional to its measure and eliminates all the alternatives not belonging to the selected branch. The process continues until a single alternative remains. . . pretree is used to investigate, theoretically and experimentally, the effect of am imposed agenda on the probability of choice" (542 from abstract).

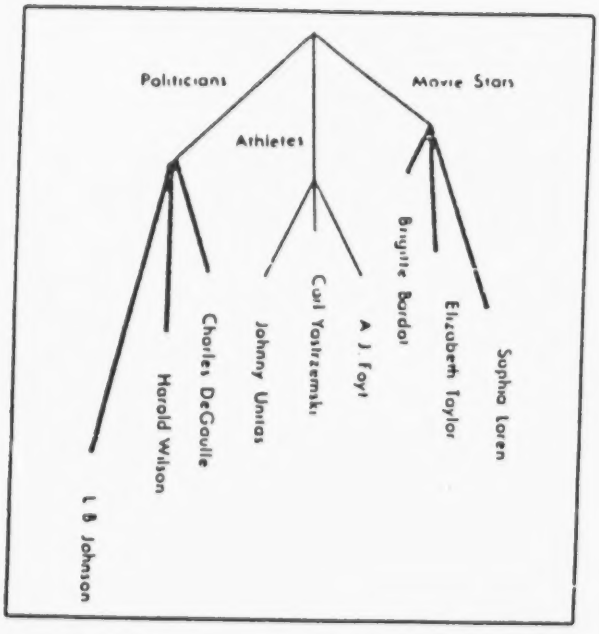


Figure 7. Preference tree for choice among celebrities.

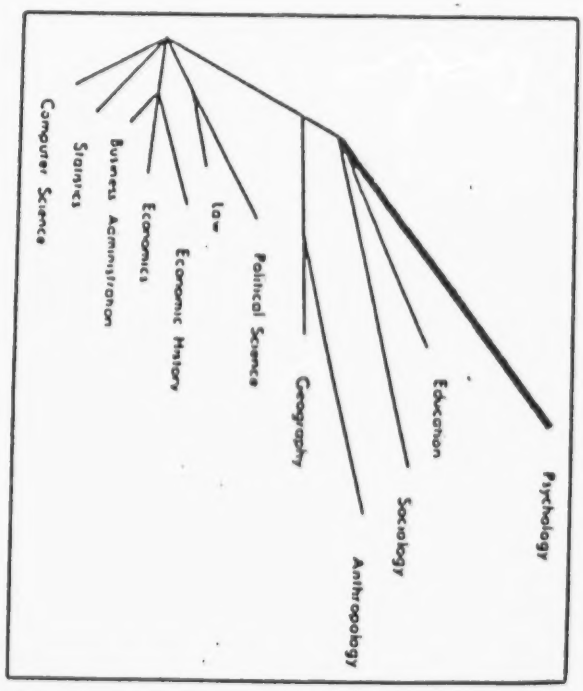
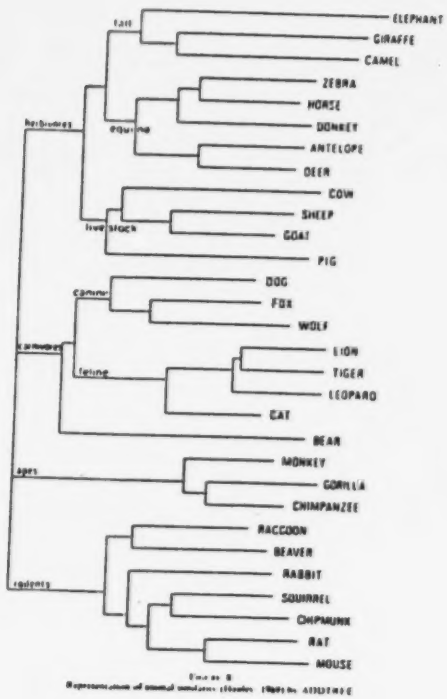


Figure 11. Preference tree for choice among social sciences.

Another article by the same authors describes use of ADDTREE, a computer program, for the representation of similarity data. Examples of three types of additive trees are shown and compared with "multidimensional scaling from both empirical and theoretical standpoints" (319). In an additive tree, as shown here, "each arc defines a cluster which consists of all the objects that follow from it. Thus, each arc can be interpreted as the features shared by all objects in that cluster and by them alone. The length of the arc can thus be viewed as the weight of the respective features, or as a measure of the distinctiveness of the respective cluster. For example, the apes (in this representation) form a highly distinctive cluster because the arc labeled 'apes' is very long" (332) (1-Animals, 2-Swedish letters, 3) Occupations).



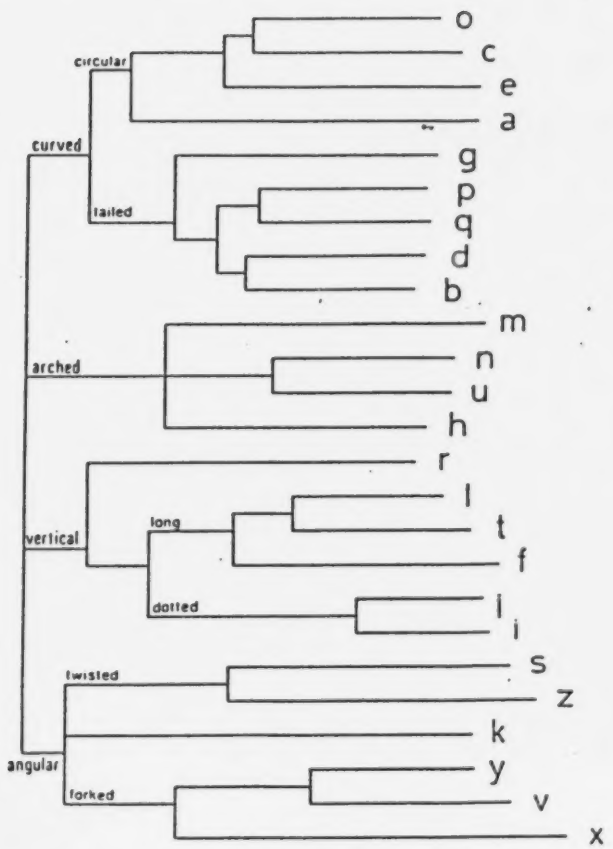


FIGURE 10
Representation of letter similarity (Kuennapas and Janson, 1969) by ADDTREE.

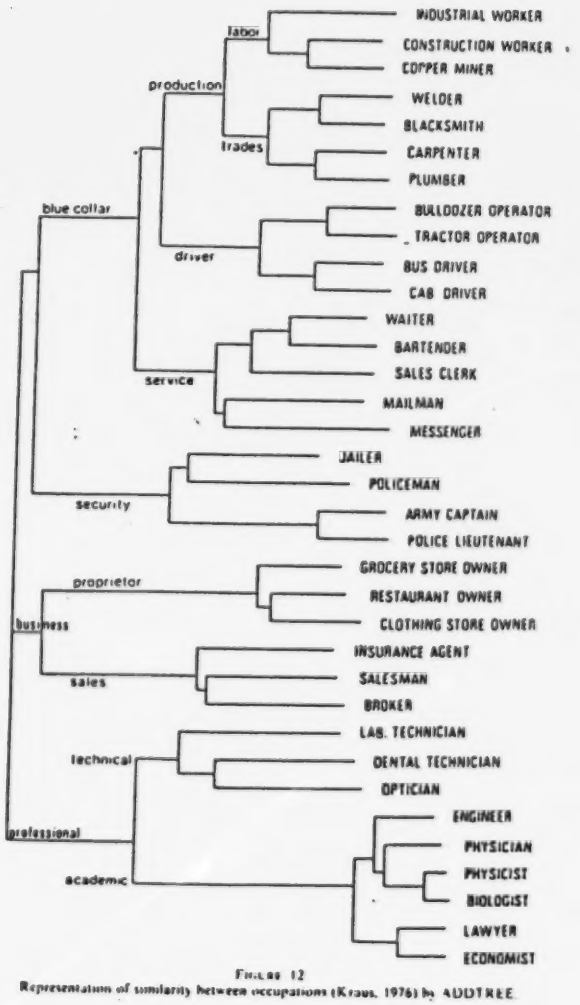


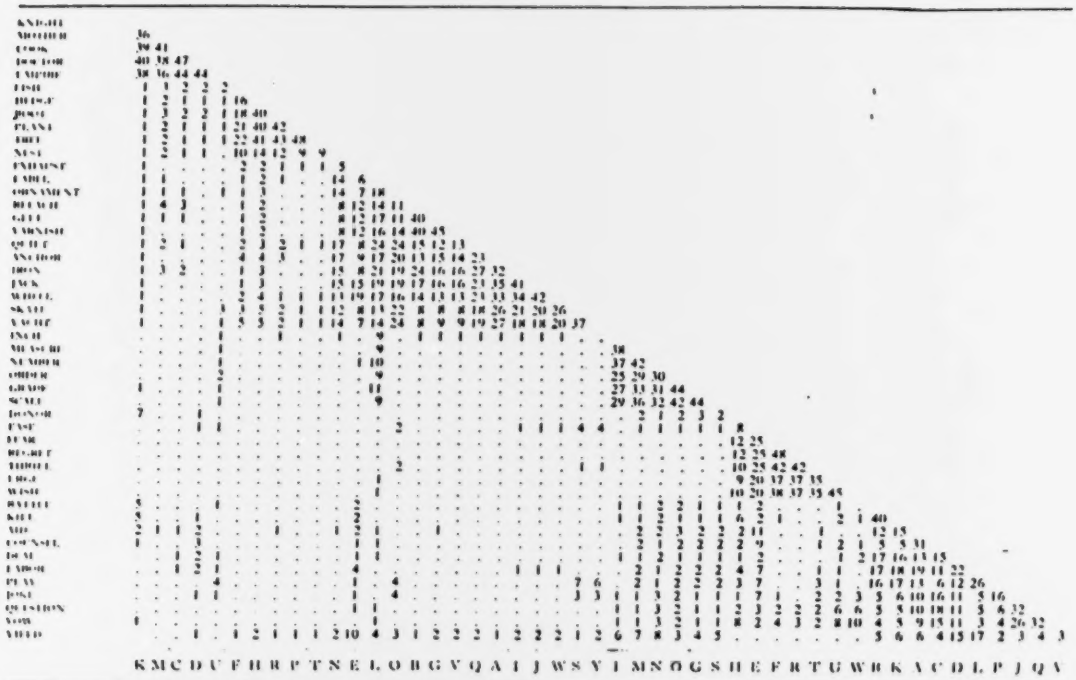
FIGURE 12
Representation of similarity between occupations (Kraus, 1976) by ADDTREE.

George H. Miller, of Rockefeller University (the place with no students, just researchers ?) says "Part of knowing a language is knowing vocabulary, and it is an appropriate psychological question to ask how this lexical information is subjectively organized and stored. . . . There are multiple interrelations and cross-references in our subjective lexicon" (169). In a paper entitled "A Psychological Method to Investigate Verbal Concepts" a method of sorting 48 common nouns "into clusters on the basis of 'similarity of meaning'" is reported. Data from several judges who sorted the words was pooled(169).

Data from lable I (Sorting Data for 48 English Nouns) has been represented as tree graphs of cluster analysis. "According to the connectedness method, the distance of an item to a cluster is its distance to the nearest member of the cluster. According to the diameter method, the distance of an item to a cluster is its distance to the farthest member of the cluster. In a perfect hierarchical clustering scheme the two methods would give the same results. Here, clusters which are common to the two methods of analysis are indicated by open circles at the appropriate nodes" (180). The author concluded "about 70% of the clusters indicated by the two methods are common to both " (181).

TABLE I

SORTING DATA FOR 48 ENGLISH NOUNS



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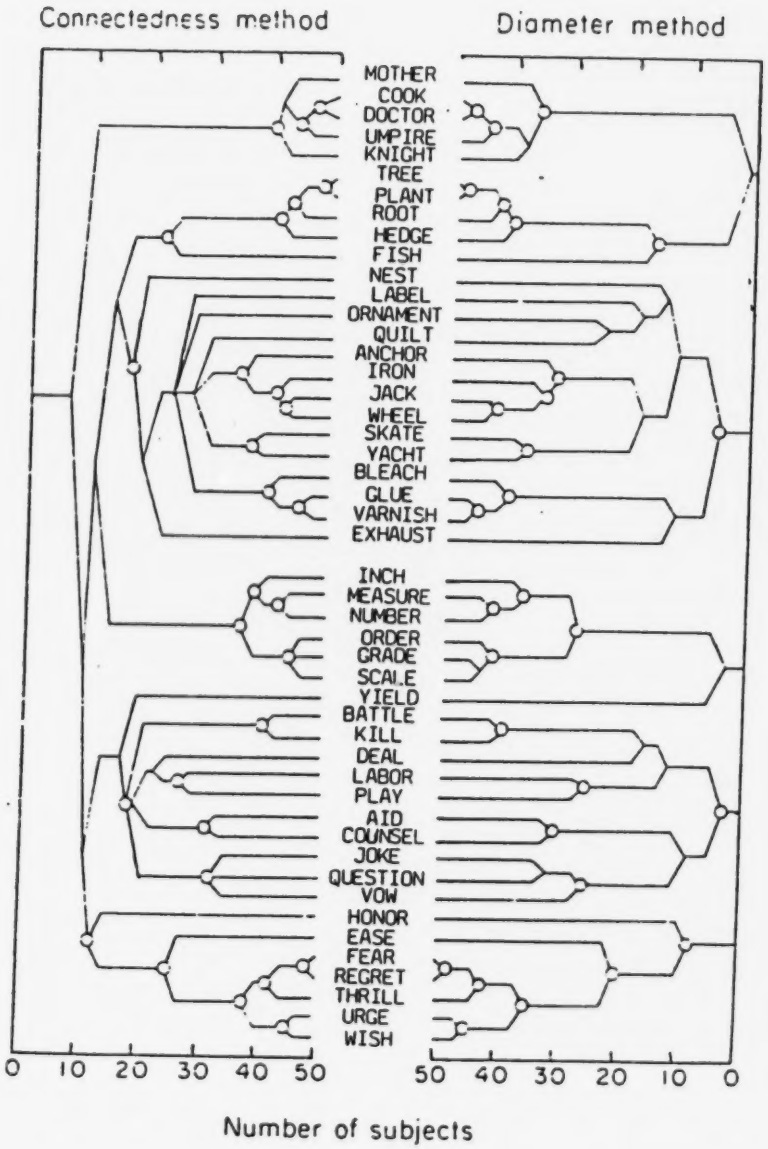

FIG. 2. Tree graphs of cluster analysis applied to data on 48 English nouns sorted by 50 judges (see Table 1). According to the connectedness method, the distance of an item to a cluster is its distance to the nearest member of the cluster. According to the diameter method, the distance of an item to a cluster is its distance to the farthest member of the cluster. In a perfect hierarchical clustering scheme to two methods would give the same results. Here, clusters which are common to the two methods of analysis are indicated by open circles at the appropriate nodes.

J. A. Hartigan of Princeton, illustrated "construction technique applied to voting behaviour of the 50 United States in the [last] 13 presidential elections, giving a tree clustering of the states." Details of the graphing procedure are given in the article. The tree is based on "correlation of the Democratic percentage of Presidential vote, 1916-1964" (1140).

AMERICAN STATISTICAL ASSOCIATION JOURNAL, DECEMBER 1967

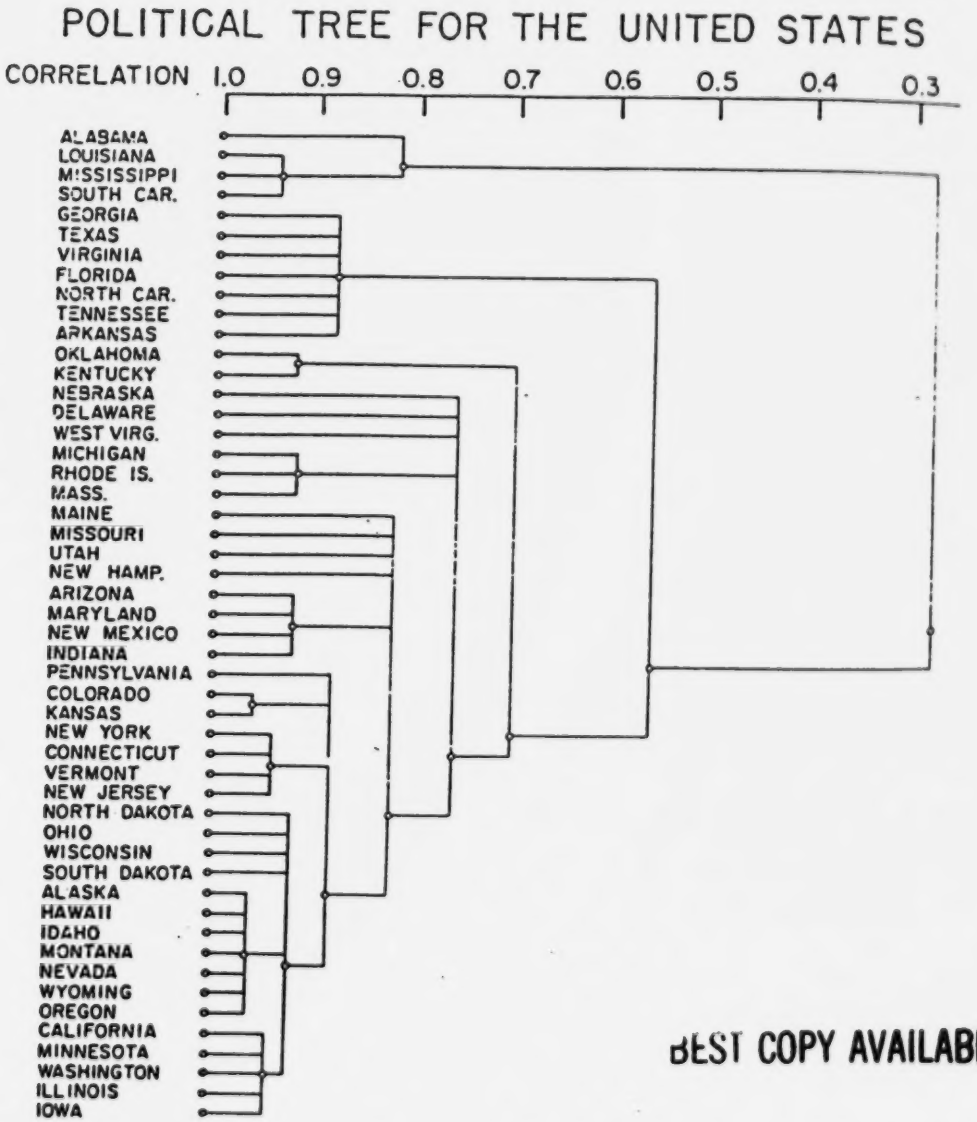

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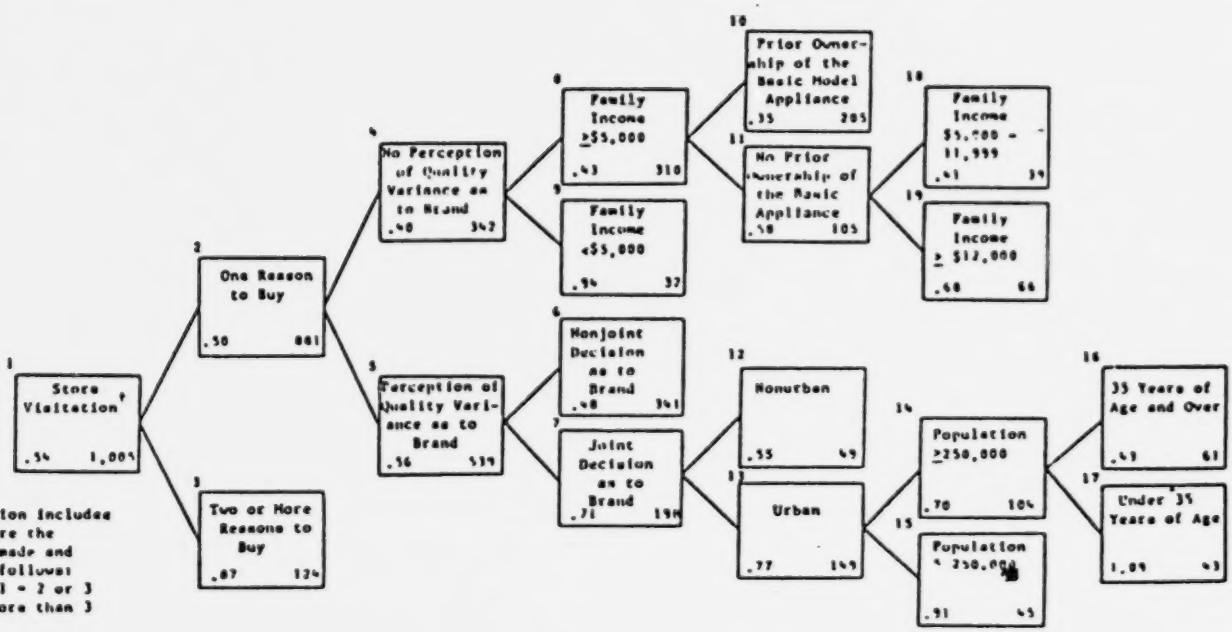
FIG. 2

Here is a different type of tree, AID stands for Automatic Interaction Detection. This tree is concerned with providing "insights into the cost-value implications of retail store visitation...by relating the extent of retail store visitation to both consumer characteristics and situational variables in the context of a major applicance purchase." A table giving "Predictor Variables" for the analysis lists "consumer characteristics" and "Situational Variables" (213) [The input for the AID algorithm consists of 1,005 purchases of a major home applicance during 1974].

AID TREE FOR RETAIL STORE VISITATION[ab]

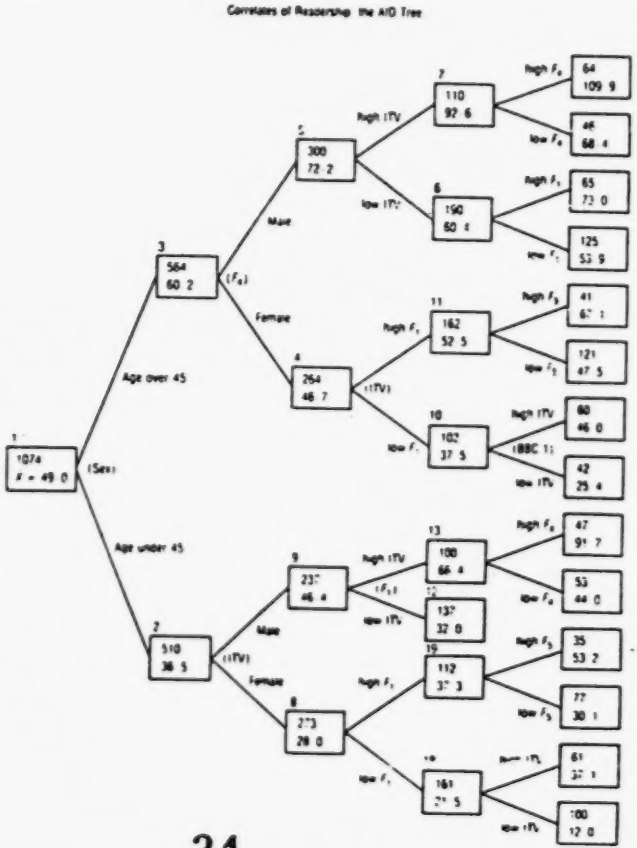


[a]Store visitation includes the store where the purchase was made and was coded as follows: 0 = 1 store; 1 = 2 or 3 stores; 2 = more than 3 stores.

[a]Store visitation means appear in the lower left corner and number of respondents in the lower right corner of each box.

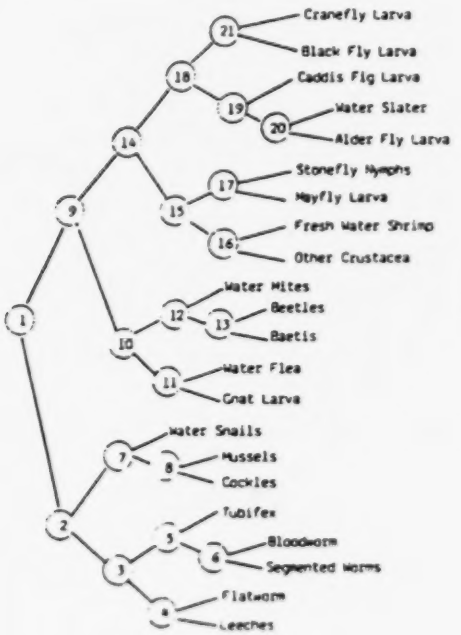
[b]Minor missing values appear as categories in groups 2, 4, 7, 8, 10, 16 and 19.

Doyle and Fenwick's article makes an analysis of "a 1972 study of the Sunday reading habits of a representative sample of over 2000 adults in the United Kingdom. In personal interviews, respondents provided information about media usage, attitudes, and a large number of socio-economic characteristics. This article relates to one aspect of media usage--time spent reading newspapers. . . A goal of the research reported here was to determine the characteristics of these readers" (82). The tree "Correlates of Readership" appeared to indicate that the "heaviest readers are older males, are heavy watchers of ITV, and have strong 'male interests'. By contrast, younger women who were low ITV viewers and interested in articles about "people" read on average little more than one tenth of the time spent by the heaviest readers. . ." (82).



Classification in one way or another, takes place in most disciplines, Alex Lake and Geoffrey Strack reported in the April 1986 issue of The Computing Teacher advantages of a program called Identify in which students may extract one field from a file, and then formulate and insert questions that will divide up to form a binary key tree. According to the authors, using this computer program saves time, is more flexible, and has increased the quality of student studies in field work in biology courses (13). A sample print-out looks like this.

The Computing Teacher
April 1986
page 13



1) Does it have legs?
2) Does it have a shell?
3) Is it cylinder shaped?
4) Does it glide along the bottom?
5) Are there lots of them together?
6) Are they transparent?
7) One shell?
8) Large shell?
9) Lives on the bottom?
10) Swims swiftly?
11) Roundish?
12) Small and round?
13) Rounded back?
14) Slow mover?
15) Clings to stones?
16) Swims on its side?
17) Two tail prongs?
18) Cylinder Shaped?
19) Case of sticks or stones?
20) Like a woodlice?
21) Like a large maggot?

Figure 1.
Dichotomous key produced from the program Identify and used by students to aid identification in the field. Students insert questions and input the organisms according to whether the organism has the attribute or not.

Items of especial interest to scholarly researchers are found in Mathematics in the Archaeological and Historical Sciences, a report of a 1970 Anglo-Romanian Conference. Haigh's "Manuscript Linkage Problem" gives illustrations of an algorithm for establishing "the maximum likelihood choice as root." Without showing the computations on which these trees are based, they will simply indicate the nature of some literary research that was done under the heading of "Filiation of Manuscripts" (399).

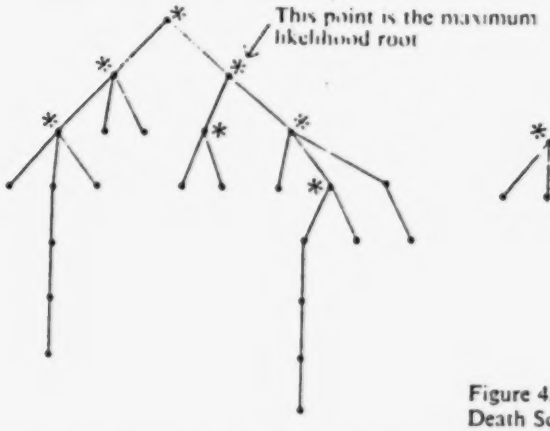


Figure 3. The reconstructed family tree of Caedmon's Hymn (Dobbie 1937)

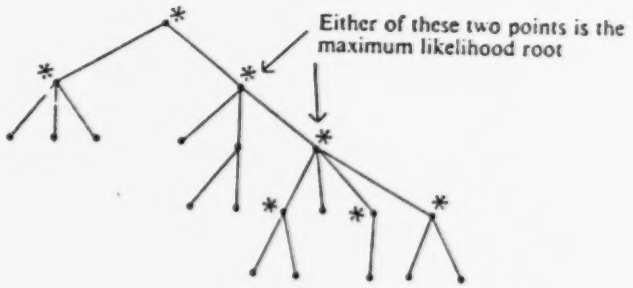


Figure 4. The reconstructed family tree of the Continental Version of Bede's Death Song (Dobbie 1937)

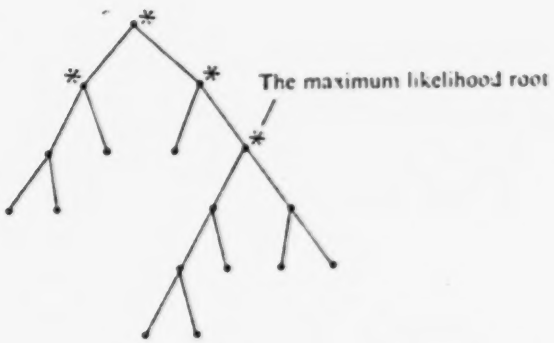


Figure 5. The stemma of Cicero's Letters to Atticus (Shackleton Bailey 1965)

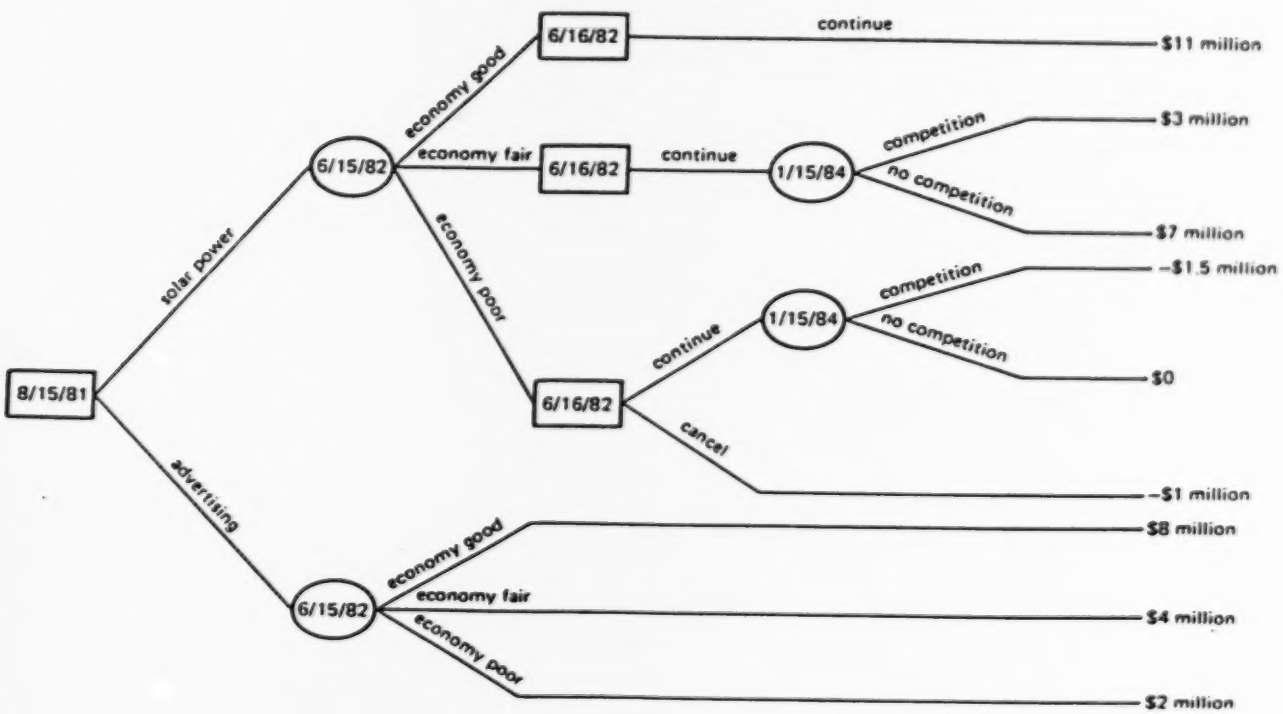
Braverman's trees indicate a sequence of timed events or circumstances.

> The decision dates are entered at each decision node and then checked to be sure that all the alternatives branching from that node are available at that date and that an irrevocable choice of one of those alternatives must be made at that date. The resolution dates are also entered at each chance node. . . Finally, the entire decision diagram should be checked to be sure that the proper chronological order is maintained when reading from left to right (79). . . In a sense, the decision tree is like a roadmap. If the decision maker selects a_1 and nature chooses s_1, the path leads to the consequence (80). . . It is helpful to prune or simplify a tree by eliminating branches whenever possible (84).

This tree illustrates Braverman's method.

SUMMARY OF THE CASE: On August 15 the president of Thermocal must make a "recommendation to the board of directors, on whether to proceed with the development of a new solar power system, initiate a new advertising campaign, or maintain the status quo" (93). Status quo was eliminated and not considered in the decision, rather than probabilities, the states of nature uch as "economy good" or "economy poor and competition" are shown on the branches. The figures at the end of the branches represent expected profits or losses.

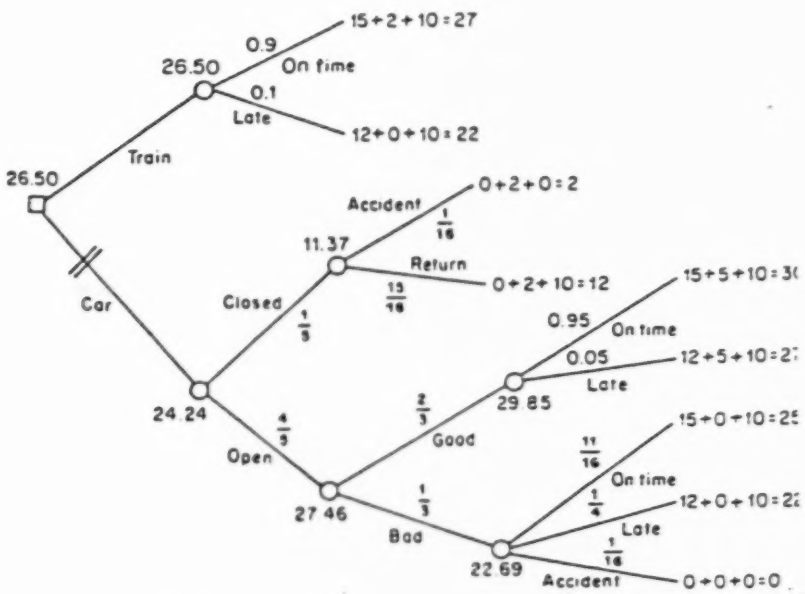
FIGURE 6.20 Complete decision tree for Thermocal multistage decision situation.



Another time related tree is the mountain-pass example given by Lindley. Lindley comments that

> Like a real tree, a decision tree contains several parts that act together, or cohere. Our method solves the easier problems that occur at the different parts of the tree and then uses the rules of probability to make them cohere. . . It is the coherence that is the principal novelty and the major tool in what we do (139).

He says that this is a simple tree with simple analysis but hard to assess because of the "non-quantitative nature of the problem in its original formulation" (154). A traveler is trying to decide to use his car, or take the train across a mountain chain in winter, in order to attend a meeting. We are reminded that the values inserted represent the individual's preferences, and could be changed but they do achieve coherence. Utility values must cohere with related quantities in decision problems.



Meeting		Journey		Car	
On time:	15	Good:	5	No accident:	10
Late:	12	Indifferent:	2	Accident:	0
Missed:	0	Bad:	0		

Figure 8.5. Decision tree for the mountain-pass example

Taming the Statistical Beast

Source: Cartoon by Tony Hall. From Sarah M. Dinham. *Exploring Statistics: An Introduction for Psychology and Education* title page. Copyright 1976 by Wadsworth, Inc. Reprinted by permission of the publisher, Brooks/Cole Publishing Co., Monterey, Calif. 93940.

Wm. G. Zikmund. Business Research Methods.
New York: Dryden Press, 1984. Ch. 13, p. 210.

SLIDES "From Family Trees to Decision Trees"

Cartoon (soup tasting)

1 - Human Hierarchy

2 - Hierarchy of Personal Achievement

3 - Hierarchy for Choosing a School

4 - Three jobs for new Ph.D.
5 - Pairwise Comparison Scale
6 - Three jobs for new Ph. D. (with calculations)

7 - Family Tree - Genealogy of Psychology

8 - Probability tree for penny tossing

9 - Worth tree for purchase of a Home
10 - Worth Tree Table for three homes

11 - Saaty's Hierarchy for Purchasing a House
12 - Saaty's Architectural Space

13 - Rubinstein's relevance tree - "Best Job"
14 - Best Auto (Trobian)
15 - Rubinstein's Nine Steps to construct relevance trees

16 - Francoeur's Widow - Decision Tree 10-1
17 - Francoeur's Probability Table
18 - Francoeur's Decision Tree 10-2
19 - Francoeur's Decision Tree 10-3
20 - Different Types of Additive Trees
21 - Huffman Code Tree Construction Algorithm
22 - Social Work Agency - Partial Value Assessment
23 - Preference Trees
24 - ADDTREE similarities - Animals
25 - - Letters
26 - - Occupations
27 - 48 common nouns - Table
28 - 48 common nouns tree
29 - Political Tree
30 - AID Tree - Retail Store
31 - AID Tree - Correlates of Readership
32 - Classification: Identify Biology Field Work
33 - MSS Linkage Problem
34 - Braverman's Time Sequence Decision Tree
35 - Mountain Pass Tree
36 - Summary of AHP
37 - Statistical Beast

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